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APPLICATION FOR U.S. LETTERS PATENT**

Title:

**INTERCONNECT LINE SELECTIVELY ISOLATED FROM AN
UNDERLYING CONTACT PLUG**

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INTERCONNECT LINE SELECTIVELY ISOLATED FROM AN UNDERLYING CONTACT PLUG

[0001] This application is a continuation-in-part of U.S. patent application number 09/595,922, filed June 16, 2000, now U.S. patent _____, the entirety of which is hereby incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] This invention relates to a semiconductor device and a method of manufacturing such a device, wherein signal lines (e.g., bit lines of a memory device, etc.) may be isolated from adjacent electrical conductors.

2. Discussion of the Related Art

[0003] Modern integrated circuit designers confront problems related to the need for increasingly smaller size and higher levels of integration. In the art of integrated circuit fabrication, and particularly when dealing with modern memory circuits, circuit manufacturers must design memory cells that are more densely constructed such that the basic elements making up the cell are closer together. This increasingly close proximity of the discrete electrical features

within a memory cell, such as a dynamic random access memory (DRAM) cell, becomes problematic in view of the increasing potential for shorting between adjacent electrical conductors. This shorting may cause a memory cell to function improperly or not at all.

[0004] An additional concern relating to the manufacture of integrated circuits is the increasing complexity and cost related to the necessity for diminishing size of the memory devices. The desire to utilize fewer stages of fabrication has led designers of memory cells to strive to simultaneously perform, at a given stage of fabrication, as many necessary steps as possible. An example of this may be seen in the standard technology of fabricating capacitor-over-bit-line (COB) type DRAM cells, which typically employs a process wherein all contacts to the memory cell active area are formed simultaneously. Thus, both bit line and capacitor contacts to the semiconductor substrate are formed using a single layering and etching step (utilizing material such as polysilicon), which creates contact studs, over which the additional features of the memory cell are fabricated.

[0005] Specifically, in a process such as described above, after the contact studs are formed in the memory cell, a dielectric layer is deposited and a bit line contact-hole pattern is lithographically delineated and subsequently etched down

to the top of the stud corresponding to the bit line connection to the active area on the substrate below. A conductive plug is next formed within each contact-hole, typically of doped polysilicon, and the conductive layers for the bit lines (typically silicide, polycide, or tungsten-based material) are deposited and subsequently delineated using lithographic-etching techniques. An interlayer dielectric is next deposited around the bit line and a capacitor contact-hole pattern is lithographically delineated and etched down between the formed bit lines to the tops of the studs corresponding to the capacitor bottom electrode connections to the active area on the substrate below. This fabrication step is completed when the capacitor contact-holes are then plugged with doped polysilicon or another conductor. Then the process of cell fabrication continues on to the formation of the capacitor features.

[0006] This standard method of fabricating memory cells utilizes the single-step forming of contact studs for both capacitors and bit lines, and the forming of bit line contacts and bit lines. Though this method is useful in reducing the steps required to form contacts to active areas of a substrate, it is desirable that the contacts, and subsequently the fully formed features, be located in a more densely packed array. It is also desirable to have the electrical features

and interconnects, exemplified by bit line and capacitor features, arranged in such a more densely packed array without increasing the probability of shorting.

[0007] Additionally, crystalline or contaminate defects in the conductive areas of an integrated circuit can deteriorate its operation. It is an advantage for such areas to be ultra-pure in composition.

SUMMARY

[0008] The present invention relates to integrated circuit fabrication and more particularly to selectively electrically connecting an electrical interconnect line with an associated contact to an active area and electrically isolating the interconnect line from other underlying contacts for other electrical features.

[0009] More specifically, in this invention a first interconnect line is formed over two underlying contact holes such that it is electrically connected to a first selectively deposited epitaxial silicon stud, but is electrically isolated from a second stud. The line is essentially formed over the first stud and partially over the second stud, and is thereafter electrically isolated from the second stud, thereby allowing the electrical features to be formed in closer proximity to one another for higher levels of integration.

[0010] The present invention also provides a method for efficiently connecting interconnect lines to a plurality of selected epitaxial silicon contact studs while maintaining electrical isolation from other non-selected plugs.

[0011] The above-described and other advantages and features of the invention will be more clearly understood from the following detailed description which is provided in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 and FIG. 2 show a semiconductor substrate with contact studs formed between gate structures and connecting to active areas within the substrate, in accordance with the invention. FIG. 2 shows a cross-section through line *II-II*.

[0013] FIG. 3 and FIG. 4 show the structure depicted in FIG. 1 and FIG. 2 at a subsequent stage of processing wherein caps have been formed over the contact studs, in accordance with the invention. FIG. 4 shows a cross-section through line *III-III*.

[0014] FIG. 5 and FIG. 6 show the structure depicted in FIG. 3 and FIG. 4 at a subsequent stage of processing wherein at least one bit line has been

formed over selected contact studs and is thereby connected to the underlying active areas, in accordance with the invention. FIG. 6 shows a cross-section through line *VI-VI*.

[0015] FIG. 7 and FIG. 8 show the structure depicted in FIG. 5 and FIG. 6 at a subsequent stage of processing wherein an insulating layer has been deposited over the bit line and a capacitor hole has been formed, in accordance with the invention. FIG. 8 shows a cross-section through line *VIII-VIII*.

[0016] FIG. 9 and FIG. 10 show the structure depicted in FIG. 7 and FIG. 8 at a subsequent stage of processing wherein caps have been selectively removed from atop the contact studs, in accordance with the invention. FIG. 10 shows a cross-section through line *X-X*.

[0017] FIG. 11 and FIG. 12 show the structure depicted in FIG. 9 and FIG. 10 at a subsequent stage of processing wherein a thin dielectric layer has been formed over a bit line, a bit line insulating layer, and inside a contact-hole, in accordance with the invention. FIG. 12 shows a cross-section through line *XII-XII*.

[0018] FIG. 13 and FIG. 14 show the structure depicted in FIG. 11 and FIG. 12 at a subsequent stage of processing wherein a capacitor hole has been re-etched leaving an insulating sidewall on the inside of the contact-hole, in

accordance with the invention. FIG. 14 shows a cross-section through line *XIV-XIV*.

[0019] FIG. 15 and FIG. 16 show the structure depicted in FIG. 13 and FIG. 14 at a subsequent stage of processing wherein a conductive plug has been formed inside the contact-hole, in accordance with the invention. FIG. 16 shows a cross-section through line *XVI-XVI*.

[0020] FIG. 17 depicts a processor-based system including a semiconductor device formed in accordance with the present invention, in accordance with the invention.

DETAILED DESCRIPTION

[0021] DRAM memory circuits are currently the most popular type of memory circuits used as the main memory of processor-based systems. Therefore, the invention will be discussed in connection with DRAM memory circuits for simplicity sake. However, the invention herein disclosed has broader applicability and is not limited only to DRAM memory circuits. It may be used in any other type of memory circuit, such as SRAM (static random access memory), MRAM (magnetoresistive random access memory), Flash, and

PCRAM (programmable conductor random access memory), etc., as well as in any other circuit in which electrical contacts are formed in close proximity to, and intended to be insulated from, other circuit devices.

[0022] Also, the terms “wafer” and “substrate” are used interchangeably and are to be understood as including silicon, silicon-on-insulator (SOI), and silicon-on-sapphire (SOS) technology, doped and undoped semiconductors, and other semiconductor structures. Furthermore, references to a “wafer” or “substrate” in the following description, do not exclude previous processing steps utilized to form regions or junctions in or on the base semiconductor structure or foundation.

[0023] No particular order is required for the method steps described below, with the exception of those logically requiring the results of prior steps. Accordingly, while many of the steps discussed below are discussed as being performed in an exemplary order, this order may be altered.

[0024] The present invention relates to a semiconductor device and a method of fabricating the same whereby electrical features in close proximity to one another may be electrically isolated, thereby reducing the potential for undesirable shorting.

[0025] FIG. 1 and FIG. 2 show a DRAM cell array at an early stage of cell formation. Active areas 12a and 12b with surrounding isolation trenches 11 are formed in a substrate 10. Gate structures, including wordline gates 14 and isolation gates 16, are formed over the substrate by techniques known in the art. Though not necessary to the invention herein disclosed, active areas (e.g., source and drain areas 12a and 12b) are typically formed by ion implantation into the silicon substrate, isolation trenches 11 are typically formed by etching trenches in the substrate followed by filling the trenches with a dielectric material, such as an oxide, and the gate structures 14, 16 are typically formed by depositing onto the semiconductor substrate a thin gate oxide followed by a conductive material such as polysilicon, then a lower resistance metal such as tungsten or a silicide such as WSi or TiSi, although other materials can be used as well. The gate pattern is defined by etching into the multilayer structure down to the substrate to define wordline gates 14 and isolation gates 16, after which the substrate is implanted with various dopants to form the active area source and drain regions 12a, 12b, for transistors. A dielectric sidewall spacer and cap (not shown) are also typically formed around and over the gate stacks to aid in the implantation process for transistor formation and to separate the gate from the contacts required to connect the active areas on both sides of the gate. The gates of access transistors

of a DRAM cell are typically laid out as a wordline gate 14, which is typically located between a bit line contact and a capacitor contact, and the isolation gate 16 is typically used to electrically disconnect or isolate active areas 12a, 12b on both sides of the isolation gate 16 and also to assist in certain self-aligned fabrication processes.

[0026] As depicted in FIG. 1 and FIG. 2, an insulating dielectric layer 18 (e.g., silicon dioxide or BPSG, etc.) is deposited over and around the gate structures 14 and 16. Next, using standard photolithography techniques, such as ion plasma dry etching techniques, holes (not shown) for contact studs 22 are formed to expose the active areas 12a, 12b in the substrate 10. This is followed by forming the contact studs 22 themselves within the holes and over the active areas 12a, 12b.

[0027] The contact studs 22 are preferably formed by selective deposition of epitaxial silicon. The selective epitaxy technique of silicon deposition involves initiating epitaxial growth on the substrate of single crystal material. The epitaxial silicon selectively grows only over the exposed silicon of the substrate 10, within the holes and elsewhere over the substrate if desired. After filling the holes, the epitaxial silicon is made appropriately conductive by doping by implanting ions (here of n-type conductivity). Utilizing selectively deposited

epitaxial silicon allows for the conductive contacts to be free of contaminants and impurities, which improves overall device functioning.

[0028] An alternative method of forming the contact studs 22 is by depositing polycrystalline silicon by LPCVD (low pressure chemical vapor deposition) utilizing silane and a dopant such as phosphine (for n-type studs) to fill the holes to form the contact studs 22. Regardless of whether the contact studs 22 are formed by preferred or alternative methods, excess epitaxial silicon or polysilicon on top of the dielectric layer 18 is removed, for example, by a dry etch-back, a wet etch-back, or CMP technique. Some of the contact studs 22a, will form electrical contacts with the bit lines 26 (see FIG. 6), while other contact studs 22b will form electrical contacts (see FIG. 16) for capacitor bottom electrodes; however all contact studs 22a and 22b can be formed simultaneously.

[0029] Referring to FIG. 3 and FIG. 4, after the contact studs 22a, 22b are formed, silicide caps 24 are formed over the tops of the contact studs 22a, 22b. These silicide caps 24 are formed by selective CVD-deposition of a metal, preferably Ti to form TiSi_2 . After metal deposition, the wafer is annealed to initiate a thermal reaction to create the silicide, then any unreacted metal is removed. The preferred material utilized to form the silicide caps 24 includes

any metals in Groups IVB, VB, VIB, and VIII of the periodic table, with Ti, Co, W, Mo, and Ni being the most common.

[0030] Due to the selective silicide formation, the contact stud 22a, 22b on which the silicide cap 24 is formed must be made of silicon, either entirely or at least the portion near the top thereof, in order to provide a silicon layer with which to react a metal to form the silicide. The preferred epitaxial silicon stud material is especially appropriate in this regard.

[0031] After the forming of the silicide caps 24, interconnect lines, e.g., bit lines 26, are next formed over selected contact studs 22a and associated silicide cap 24 structures. The bit lines 26 are formed by depositing a conductive layer over the silicide caps 24 and the insulating dielectric layer 18, by any standard method known in the art such as PVD or CVD deposition, and then etching the conductive layer to form bit lines 26. As shown in FIG. 5, the bit lines 26 are not necessarily straight. FIG. 5 and FIG. 6 show the bit lines 26, which are delineated from the deposited conductive layer and etched by standard techniques in the art, for example by masking the bit line 26 using any standard photolithography and dry-etching process. As a result, bit lines 26 are formed over some of the contact studs 22a and the associated silicide caps 24 and partially overlying other contact studs 22b and associated silicide caps 24. When

the bit lines 26 are formed by etching, the contact studs 22b intended to be contacts for the lower capacitor electrodes are re-exposed. Because the bit lines 26 are not straight, they can be defined to interconnect devices formed in non-linear alignments on the substrate 10. This contributes to the increased density of integrated circuit.

[0032] After the formation of the bit lines 26, an interlayer dielectric layer 28 is deposited over and around the bit lines 26. There is no specific preferred material for this interlayer dielectric other than those known in the art which can withstand the selective silicide etch used in subsequent processing steps (such as silicon nitride or BPSG, etc.). This interlayer dielectric layer 28 is then patterned with photoresist and etched by ion plasma dry etching, as shown in FIG. 7 and FIG. 8, to form contact-holes 30 to the silicide caps 24 over the contact studs 22b. These contact studs 22b are those not positioned directly beneath the now formed bit lines 26, but may be in partial contact with the bit lines 26, as shown by area 27 in FIG. 8. Contact studs 22b are intended to be contacts for features of the integrated circuit other than the directly-overlying interconnect line, here those other features are capacitors, but can be other devices as well.

[0033] Contact studs 22b, shown in FIG. 8, may be in partial contact 27 with the overlying bit lines 26 due to possible overlap of the bit lines 26 with the

silicide caps 24 on contact studs 22b caused during the bit line deposition and delineation (see FIG. 5 and 6) 22, resulting from the close proximity of these electrical features. This allowance for partial contact contributes to the increased density of the integrated circuit.

[0034] This direct electrical connection 27 is next removed as explained in connection with FIG. 9 and FIG. 10. The exposed silicide caps 24 over contact studs 22b are selectively etched with a negligible effect upon the surrounding structures. This selective etch is accomplished by choosing an etch that can etch the silicide away without significantly affecting the bit line 26. For instance, if the bit line is formed of tungsten and the silicide is TiSi_2 , a dilute HF acid solution can remove the silicide without affecting the tungsten bit line. A wet etch, and potentially even an isotropic dry etch, may be used to remove the silicide caps 24 from the contact studs 22b, portions of which may be below the bit lines 26, as shown in FIG. 10.

[0035] Now that any direct electrical connection between the bit line 26 and the underlying contact stud 22b has been removed, these two electrical features must be further insulated to ensure against undesired potential shorting between them. As shown in FIG. 11 and FIG. 12, a thin dielectric layer 32 (such as SiO_2 or Si_3N_4) is deposited over the interlayer dielectric layer 28 and

within the contact-holes 30. This thin dielectric layer 32 is deposited using a highly-conformal technique such as CVD to ensure uniform thickness on the interior sides of the contact-holes 30. A preferred material for the thin dielectric layer 32 is silicon nitride.

[0036] As shown by FIG. 13 and FIG. 14, the thin dielectric layer 32 is next etched to re-expose the contact stud 22b and leave an insulating sidewall 34 inside the contact-hole 30, thereby preventing unintended electrical connection and shorting between the bit line 26 and the contact stud 22b, or with a conductive plug 36, which will be deposited in the hole 30. The thin dielectric layer 32 may be etched by any satisfactory method known in the art.

[0037] The contact-hole 30 is next filled with a conductive material, such as doped epitaxial silicon, doped polysilicon, or metal, depending upon the physical characteristics of the future overlying capacitor (material, type, structure, etc.) to form a conductive plug 36 as shown in FIG. 15 and FIG. 16. In the preferred embodiment, where the contact studs 22 are formed of selectively deposited epitaxial silicon, the conductive plug 36 can likewise be formed of selectively deposited epitaxial silicon. If the overlying capacitor is to be polysilicon based (that is, having a polysilicon bottom electrode) then for ease in manufacture the capacitor conductive plug 36 should also be polysilicon.

However, if the overlying capacitor is to be metal-based (having a bottom electrode consisting of a metal such as W, TiN, Pt, Ru, Al, or any other metal from Groups IVB, VB, VIB, VIII, IB, IIB, or IIIA of the Periodic Table, or of an alloy, oxide, nitride, carbide, boride, or other combination thereof) then the capacitor conductive plug 36 should also be a metal.

[0038] After the formation of the conductive plug 36, standard processing as known in the art may be used to complete the memory device, including conventional capacitor formation and cell metalization to form a completed memory cell.

[0039] Although the capacitor conductive plug 36 and overlying capacitor bottom electrode have been described in separate steps, as another embodiment, the interlayer dielectric layer 28 may be deposited to a thickness such that formation of a capacitor within that thickness would achieve sufficient surface area for storage of a charge required for memory cell operation. The contact-hole 30 may be etched through the interlayer dielectric layer 28 down to the silicide cap and all subsequent processing heretofore described could be used to simultaneously form both the capacitor conductive plug 36 and the bottom electrode of the capacitor. Hence, after the thin dielectric layer 32 etching back step, an epitaxial silicon or thin polysilicon layer could be deposited that acts as

both the conductive plug 36 and the bottom electrode of the capacitor. Instead of polysilicon, a metal-based layer could likewise be deposited to act as both the conductive plug 36 and the capacitor bottom electrode. After these steps, standard processing as known in the art may be used to complete the memory device, including further conventional capacitor formation steps and cell metalization to form a completed memory cell.

[0040] In another embodiment, the invention may also be used if a silicide cap is not provided over the contact studs 22a, 22b. In such a configuration, the interconnect lines 26 are connected directly to selected contact studs 22a and other non-selected contact studs 22b are isolated from the interconnect lines by the selective removal of an upper-portion of the non-selected contact studs 22b, as opposed to the selective removal of the silicide caps 24 described above. The removed upper-portion of the contact studs should generally conform in thickness to the similarly removed silicide caps 24 described above with respect to FIG. 13 of the first embodiment. After removal of the upper-portion of the non-selected contact studs 22b, the structure shown in FIG. 10 is attained and the subsequent processing described and illustrated with respect to FIG. 11 to FIG. 16 is carried out.

[0041] FIG. 17 illustrates a processor-based system (e.g., a computer system), with which a memory having memory cells constructed as described above may be used. The processor-based system comprises a central processing unit (CPU) 102, a memory circuit 104, and an input/output device (I/O) 100. The memory circuit 104 can contain a DRAM (or other) memory circuit including semiconductor devices constructed in accordance with the present invention. Also, the CPU 102 may itself be an integrated processor which utilizes semiconductor devices constructed in accordance with the present invention, and both the CPU 102 and the memory circuit 104 may be integrated on a single chip.

[0042] Although the (COB) DRAM structure used in both the example of the existing related art and in the invention described has a particular layout and is of 6F² design, this does not preclude application of this invention to any other COB DRAM design, nor to any other particular semiconductor device, so long as it is necessary to electrically connect an interconnect line to one particular underlying contact stud while electrically isolating it from another closely positioned or partially underlying contact stud. For other devices, this invention could be applied wherever an interconnect line needs to be connected to one contact while remaining isolated from an adjacent contact, especially when the

tight spacing between the contacts will not allow sufficient room for routing of the line away from the contact to remain isolated.

[0043] The above description and accompanying drawings are only illustrative of exemplary embodiments, which can achieve the features and advantages of the present invention. It is not intended that the invention be limited to the embodiments shown and described in detail herein. The invention can be modified to incorporate any number of unforeseeable variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. The invention is only limited by the scope of the following claims.

[0044] What is claimed as new and desired to be protected by Letters Patent of the United States is: